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ORD PROJECT REPORT PR 2003/03

MULTI-CREWING
THE MARITIME COASTAL DEFENCE VESSELS?

By

Dr D. ALLEN and Dr P.M. BENOIT

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OTTAWA, CANADA

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Recommended by: ______________________ DOR(MLA)

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OTTAWA, ONTARIO March 2003

ABSTRACT

The tasks assigned to the Kingston class Maritime Coastal Defence Vessels (MCDV) have strained the existing crew and ship resources. A study by Benoit and Massel (2001) demonstrated that, on average, 95% of the available time-in-schedule was utilized, leaving little scheduling flexibility. The present study examined the policy of using multiple crews on the MCDV to determine if any scheduling improvements were possible. The results showed that multi-crewing is unlikely to yield gains in availability for at-sea tasking. The possible consequences of implementing the policy–on infrastructure, training requirements and crew cohesion–were also discussed. The methodology and analysis approach can be applied to other classes of ship.

RÉSUMÉ

Les tâches exigées des vaisseaux de défense côtière maritime (VDCM) de la classe Kingston ont imposé beaucoup de pression sur les équipages et les ressources des navires. Une étude antérieure par Benoit et Massel (2001) a montré que les tâches exigées nécessitent l'utilisation des VDCM à 95% de leur disponibilité. Ceci laisse peu de flexibilité à la planification de leur tâches. L'étude présente examine si la disponibilité des VDCM peut être augmentée en utilisant une nouvelle pratique où plus d'un équipage peut commander le même vaisseau à différents moments de l'année. Les résultats obtenus montrent que pour les vaisseaux de la classe Kingston, il est très peu probable que des gains soient obtenus. Les conséquences d'une telle pratique sur les infrastructures, les entraînements requis et sur les liens d'appartenance des membres d'équipage sont discutées. La méthodologie développée peut aussi être appliquée à d'autres classes de vaisseaux.

EXECUTIVE SUMMARY

INTRODUCTION

This report documents work done for the Directorate for Maritime Policy, Operations and Readiness (DMPOR), to determine if there are any benefits achievable by allowing crews to change from one ship to another on a regular basis during the year (multi-crewing). The Maritime Operational Research Team (MORT) was tasked with this study, and the analysis focused on the class of ship known as the Maritime Coastal Defence Vessel (MCDV).

AIM

The first aim of the study was to determine if the amount of available "at-sea" time of the MCDV fleet could be increased without infringing on the quality of life of the crew. The study investigated the impact on at-sea time, for the hypothetical case where ships have multiple crews in the course of a year. Multiple crews can mean maintaining more crews than ships, or, alternatively keeping the same number of crews as ships but scheduled differently.

A second aim of the project was to develop a methodology that would allow similar questions to be addressed for the other classes of ships in the Canadian Navy.

OVERVIEW OF MULTI-CREWING

In the current practice, each crew is assigned to a single ship throughout the year. Thus, a crew can be on duty at sea if both the crew and its ship are available.

Within a multi-crewing practice, there is less restriction on the at-sea availability. The premise is that each available crew can man any ship available to go to sea. It is thus natural to expect higher overall at-sea availability of MCDV vessels using a multi-crewing practice. However, to determine the usefulness of multi-crewing, one must consider the total availability and also the resulting effective at-sea time. The difference between the *available* at-sea time and the *effective* at-sea time is due to the cost (in personnel time) associated with hull changes. A hull change requires the need to transfer materiel, to update the ship's distribution accounts, to regenerate the chart and navigation outfits, and so on. This loss in effectiveness was estimated through subject matter expert (SME) interviews.

METHODOLOGY

In addressing the question of the applicability of multi-crewing the MCDV fleet, a three-step process was developed. In step 1, an optimal ship-platform schedule was produced for the year without consideration of crewing. In step 2, crews were assigned optimally on the basis of ideal multi-crewing (i.e., no time lost at crew changeover), and in step 3, the realistic time lost due to crew changeover was added. Results were compared to the at-sea time obtained under the current practice of one crew-one ship.

The results showed no advantages to multi-crewing. Because of this result, further investigation of the consequences of making such a change to scheduling practices (e.g., implications to infrastructure, training and certification, maintenance policies, crew cohesion) was not pursued.

ASSUMPTIONS

Several assumptions were made for the study. Some were required to make the problem tractable through simulation, while others reflect the requirements imposed on the ships and crews. Those assumptions are as follows:

a. A single coast is modeled. The same results are considered to hold for both coasts.
b. The working year has 50 weeks (i.e., two weeks leave at Christmas is assumed).
c. The smallest time unit considered is one week. This implies, in particular, that each hull change occurs at the beginning (or equivalently at the end) of the week.
d. All ships maintenance periods are between three and six weeks long.
e. Each ship will be available at sea for at least three weeks between each maintenance period.
f. Each ship receives the same quantity of maintenance over the year. This quantity is imposed to satisfy the In-Service-Support-Concept (ISSC) contract.
g. Each crew is considered as a single unit. The effects of changing personnel within a crew were not considered.
h. Each crew has three weeks leave during the summer.
i. The same amount of tasks ashore is required from all crews.

j. Two ships and crews must be available for 10 consecutive weeks twice in the year for the purpose of conducting MARS IV training on each coast.
k. At least two ships and crews must be available for at-sea tasking at all times (except Christmas) on each coast.

Effectiveness of Multi-Crewing

The effectiveness of multi-crewing was investigated for different situations. Cases with five or six crews manning[1] five or six ships were analyzed. The results show that no gain in effective at-sea time is obtained by using a multi-crewing practice unless the amount of tasks ashore required from the crews is reduced to five weeks per year, and the time lost due to a hull change is no more than one week per change. Although it might be possible to facilitate hull changes, it is doubtful that alongside tasks could be reduced to five weeks per crew per year.

Conclusion

Under the assumptions of the study, we conclude that only small gains of the available at-sea time is obtained by using a multi-crewing practice for the MCDV fleet. Reducing the amount of alongside tasks can provide extra time for the crews and hence show promise regarding multi-crewing. But the reduction needed for the alongside tasks is considered unrealistic. Furthermore, many subject matter experts (SME) from both coasts have shown concerns in regard to such practice. The main concerns were that a multi-crewing practice would increase the amount of required training (with increased demands on the Sea Training Staff) and, that multi-crewing would have a negative influence on unit cohesion and crew morale.

The SMEs mentioned three alternatives to increase the effective at-sea time:

a. Better coordination between:
    i. the maintenance time and the contractor's availability, and
    ii. between training and school availability to reduce the time delay alongside.
b. Increase the variety of at-sea tasks for each crew: In particular, it was mentioned that *the demands and repetition of MARS IV training wears a crew down more quickly than a diverse challenging schedule.*
c. Outfit the sixth ship on each coast with a crew. This was considered by many as the ideal (and simplest) solution.

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[1] All Canadian ships have male and female sailors.

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LIST OF ILLUSTRATIONS

List of Acronyms / Glossary

BOIV	Bottom Object Inspection Vehicle
CMS	Chief Maritime Staff
CO	Commanding Officer
COMSEC	Communication Security
CSD	Customer Service Desk
DC	Damage Control
DMPOR	Directorate for Maritime Policy, Operations and Readiness
FF	Fire Fighting
HAZMAT	Hazardous Material
ISSC	In Service Support Concept (ship maintenance)
MARCORDS	Maritime Command Orders
MARLANT	Maritime Forces Atlantic
MARPAC	Maritime Forces Pacific
MARS	Maritime Surface Sub-surface (Officer classification)
MCDV	Maritime Coastal Defence Vessels
MMS	Mechanical Mine Sweeping
MORT	Maritime Operational Research Team
NABS	Navigation and Bridge Simulation
NPF	Non-Public Funds
NRD	Naval Reserve Division
OJT	On-Job Training
OPSKED	Operating Schedule
PF	Public Funds
PLD	Post Living Differential
QOL	Quality of Life
Radhaz	Radiation Hazards
RS	Route Survey
RSP	Readiness Sustainment Program
SAR	Search And Rescue
SME	Subject Matter Expert
SRI	Sea Readiness Inspection
WDO	Weapon Designated Officer
WUP	Work ups (training)

At-sea availability	Total time available over the year for at-sea tasking.
Bounds	Theoretical limit not taking the constraints into account.
Crew Demand	Number of crews required for at-sea tasking each week.
Crew Supply	Number of crews assigned to go at sea every week.
Degeneracy	More than one schedule leading to the same optimal solution.
Effective time	Time for at-sea tasking resulting after subtracting the time lost due to hull changes.
Ship-demand	Number of ships required for at-sea tasking each week.
Ship-supply	Number of ships assigned to go at sea every week.
Theoretical demand	An arbitrary demand used to find the highest at-sea availability. It does not reflect an actual at-sea tasking requirement.
Time lost	Period of time needed to "settle in" to a new ship after a hull change.

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Special thanks are due to LCdr Lorne Richardson, our point of contact in DMPOR, who provided ongoing client support during this project.

Multi-crewing the Maritime Coastal Defence Vessels?

SECTION I - INTRODUCTION

1. This report documents work done for the Directorate for Maritime Policy, Operations and Readiness (DMPOR), to determine if there are any benefits achievable by allowing crews to change from one ship to another on a regular basis during the year (multi-crewing). The Maritime Operations Research Team (MORT) was tasked at reference [1] to focus on the class of ship known as the Maritime Coastal Defence Vessel (MCDV).

2. The MCDV, or Kingston Class ship, is a general-purpose coastal patrol vessel crewed primarily by the Naval Reserve Force. In its primary role, the MCDV is assigned a variety of Mine Warfare related tasks, including route survey and mechanical minesweeping of Canada's coastal waters. The fleet of 12 MCDVs were commissioned between 1996 and 1999. Thus, the full fleet has been available for tasking by MARLANT and MARPAC Formation Commanders only for the past three years.

AIM OF THE STUDY

3. The first aim of the study is to determine if the available "at-sea" time of the MCDV fleet can be increased without infringing on the quality of life of the crew. Specifically, the study will investigate the impact on at-sea time for the hypothetical case where ships have multiple crews in the course of a year. Multiple crews can mean maintaining more crews than ships, or, alternatively keeping the same number of crews as ships, but scheduled differently.

4. A second aim of the project is to develop a methodology that will allow similar questions to be addressed for the other classes of ships in the Canadian Navy.

Overview of the Study

5. In addressing the question of the applicability of multi-crewing the MCDV fleet, the problem was divided into four tasks at the outset of the project:

Task 1: An optimal schedule of the available MCDVs will be determined (without consideration of crew restrictions) to meet a given demand for the ships (i.e., at-sea tasking);

Task 2: Based on the schedule of the MCDVs as determined in Task 1, a crew schedule will be constructed to optimize the ship/crew availability;

Task 3: When ship and crew schedules have been determined, the impact of changing crews (multi-crewing the ships) will be calculated. The residual available time will be compared to that available in the current schedule as a measure of effectiveness of the new approach.

6. Should the results of the three previous tasks indicate that available at-sea time sufficiently exceeds that currently available, the project will proceed to a fourth task, namely:

Task 4: Investigate the consequences of making such a change to scheduling practices, e.g., implications to infrastructure, training and certification, maintenance policies, crew cohesion, etc.

Outline of the Report

7. The report is divided in six parts. Section II provides background information that includes a review of a previous MORT study and provides an overview of the insights obtained from subject matter experts (SME). Section III describes the methodology used for the study. The results are given in Section IV and analyzed in section V. Section VI states the final conclusions of the study.

SECTION II - BACKGROUND

REVIEW OF PREVIOUS ANALYSIS

8. In previous work concerning the scheduling of the MCDV fleet [2] MORT analysed the impact that different demands would have on the availability and readiness of the MCDV fleet. MORT conducted a macro-level analysis of the MCDV fleet. East and West Coast fleets were considered as one unit and availability (and readiness) was assessed on a yearly basis to provide insight into the problem. Finding the right balance among the many tasks required analysis of a complex mix of competing needs and priorities.

9. In this previous study MORT set out to answer three questions:
   a. Is the MCDV fleet over-tasked?
   b. If over-tasked, how could a better 'balance' between time at sea and time ashore be obtained?
   c. What impact does the level of readiness have on MCDV availability?

10. The following assumptions were made in that study:
   a. Tasks could be equally distributed across the entire fleet of MCDVs;
   b. Tasks could be equally distributed throughout the year (no seasonal variations);
   c. There were no unpredicted delays or conflicts within the schedule;
   d. The degree of multi-tasking could not be increased significantly; and,
   e. The ship and its crew were a single entity.

11. The previous study produced the following conclusions:
   a. The MCDV fleet has more tasks to do than time to do them;
   b. Increasing the number of available ships and crews or eliminating some low priority tasks could allow the fleet to be operated in greater balance; and,
   c. Readiness levels do not significantly affect MCDV at-sea tasks.

12. As a consequence of this work, MORT was asked to extend its analysis by considering the effect of scheduling the ship and crew separately. Accordingly, the present report builds upon the efforts of the previous study and investigates the impact of producing a separate schedule for ships and crews.

OVERVIEW OF THE CONCEPT OF MULTI-CREWING

13. The term multi-crewing describes the practice where a single crew is deployed to more than one ship over the year. Such a practice could possibly increase the available at-sea time since the ship and crew availability would no longer be rigidly linked. In today's MCDV fleet each ship is assigned a single crew. This would not be the case in multi-crewing, and this potentially creates an opportunity for greater flexibility and more at-sea days. The concept of multi-crewing is that when a ship is available and its regular crew is not, another crew could be substituted, i.e., crews would observe a "change of hulls".

14. The practice of multi-crewing and hull changes is not new and has been applied to the Canadian Harbor Patrol Boats, and by the British and the Dutch Navies on some classes of ships. In this study, we analyzed multi-crewing and hull changes only for the MCDV fleet.

INPUT OF SUBJECT MATTER EXPERTS

15. The problem of multi-crewing required knowledge of MCDV operations [2], and to obtain this knowledge, several subject matter experts (SME) were interviewed on a wide range of topics – each relating to the four previously outlined tasks of this project. The SMEs were chosen with input from the project sponsor (DMPOR 3-5). East and West coast personnel were consulted, and the list of personnel included in the interviews is provided in Annex A.

16. The input of the SMEs was used to define and validate the assumptions of the study as well as provide insight into the potential problems that might arise should the policy be implemented. Details of the discussions are provided in Annex B.

SECTION III – METHODOLOGY

OVERVIEW

17. Under a multi-crewing practice, ships and crews are scheduled separately. Mathematical optimization techniques can be used to determine the largest amount of at-sea tasking that can be conducted (as mandated to fulfill the role of the MCDV). This

approach has been employed for this study. Two interdependent optimization problems appear: one for the ship, one for the crew. Each of these optimization problems takes the form:

$$\text{Min } Z(a, b, \ldots)$$

$$\text{Subject to: } a < N, \quad b < M, \ldots$$

The quantity Z is called the objective function and depends on different variables (a, $b, \ldots$) that are subject to certain constraints—indicated by the second line. The specific variables, constraints and function Z appearing in the problem at hand are described in the following subsections.

18. To give an overview of the procedure, it is useful to consider a fictional scheduling problem for a five-week period (see Figure 1). The red column represents the number of ships required each week. This is called the *ship-demand*. It may happen that an insufficient number of ships are available to meet the requirement. The ship schedule is chosen so that this ship-demand requirement is satisfied as much as possible (minimizing the gap between the red and blue columns—across all weeks). Once an optimal ship schedule has been determined, the number of hulls available each week fixes the demand for crews (blue column). One crew is needed for each hull. It may happen that an insufficient number of crews are available to meet the requirement. Thus the crew schedule is chosen so that this *crew-demand* is satisfied as much as possible (minimizing the gap between the blue and green columns). For example, in the 2nd week, five ship-weeks of tasks are required (red); however, only four ships are available, so four crews are required (blue); and finally, only three crews are actually available that week (green).

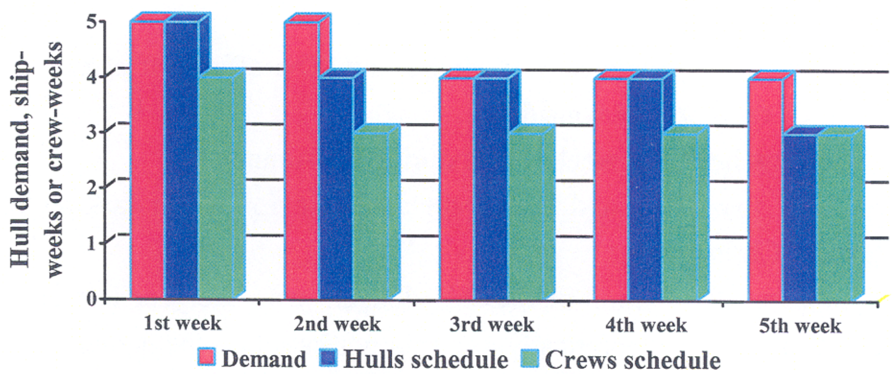


Figure 1 Illustration of the Ship-demand for at-sea Tasks, the Crew Demand, and the Actual Supply of Crews

19. To summarize, the main calculation will consist of two optimization procedures utilizing the three following factors:

a. The ship-demand = ideal number of ships needed (red column of **Figure 1**).
b. The ship-supply = actual number of available ships = crew demand (blue column of **Figure 1**).
c. The crew supply = actual number of crews available (green column of **Figure 1**).

The two optimization procedures assign crews to the ships that were assigned to the tasks. This is a weekly assignment. At this stage, no constraint imposes that a crew always mans the same ship throughout the year. A generic pair of optimal ship and crew schedules is thus expected to require hull changes by the crew. As is shown by the fictional problem, the schedules are determined on a week-to-week basis rather than day-to-day. This was necessary to make the problem tractable. The work year was set to 50 weeks, ignoring the two-week Christmas leave period.

ASSUMPTIONS

20. Before describing the methodology in more details, it is useful to list the different assumptions made:

a. A single coast is considered. The same assumptions are considered valid for both coast and the possible transfer of personnel or ship from one coast to the other is omitted.
b. The working year is divided into 50 weeks.
c. The smallest time unit considered is one week. Therefore, all tasks (ISSC, at-sea, etc.) occur in multiples of one week.
d. All ISSC periods are between three and six weeks long.
e. Each ship will be available at sea for at least three weeks between each ISSC period.
f. Each crew is considered as a single unit. The effects of changing personnel within a crew are not considered.
g. Each crew has three weeks leave during the summer.
h. At least two ships and crews are available for at-sea tasking at all times (except Christmas).
i. A uniform distribution of the ship-demand over the year is considered. This demand was set theoretically and was not based on the actual requirement on the fleet (see discussion below).

j. The maintenance required by all ships was considered uniform between all ships and was set so to satisfy the In-Service-Support-Concept (ISSC) contract (see discussion below).
k. Predetermined distribution of the maintenance periods were considered (see discussion below).
l. The amount of alongside task requested from the crews was the same for all crews. Its distribution over the year was optimally set during the maintenance periods of the ships.
m. To reduce the size of the problem, the year was divided in two periods that were called summer and winter. The summer and winter periods were set to be 22 and 28 weeks long, respectively.
n. One MARS IV training was set during the summer period and one during the winter period.
o. Two ships and crews are available for 10 consecutive weeks for the purpose of conducting each MARS IV training.

Some assumptions can be questionable. However, we will show that the conclusion of the study will remain valid even if most assumptions are modified (this will be clarified in section IV).

TASK 1 – SCHEDULING OF THE SHIPS

21. The first task was to determine an optimal ship schedule to meet a theoretical demand. Keep in mind that the crew is not considered at this stage—since we are intentionally weakening the link between a ship and a crew for analysis purposes. This task required four steps:

a. State the number of ships available (i.e., postulate a fleet size);
b. Determine a theoretical demand for these ships (defined below);
c. Create the set of possible ship schedules; and,
d. Find the optimal ship schedule, that is, the one that best meets the posited demand.

Fleet Size

22. Different options for the total number of available ships were considered. Currently six ships are available on each coast but only five of them are manned. For this study, we analyzed the situation with five and six ships available throughout the year, as well as situations with five ships available all year and an additional one available only

half the year (designated as the '5+1' option). This last option is representative of the current situation where one ship on each coast is in dry dock or in workups for 25 weeks every year (i.e., a full inspection).

The Theoretical Ship-Demand

23. The ship-demand consists of the number of ships required for at-sea tasking. The demand is specified for every week of the year. Thus, the ship-demand figures specify how the tasks are distributed over the year. It is important to notice that a theoretical demand was considered: The demand was not based on historical data. Since, we are looking for the total time that can be obtained from the fleet, the demand has to be fixed to a large value. It should be clear that since we are using an optimization procedure, if a single ship was requested for at-sea tasking per week then the optimal schedule would have only one ship on duty per week and the maximum time that could be obtained out of the fleet would be unknown. Let $d(w)$ represents the ship-demand for the wth week, where w takes on the values 1, 2,... 50 for each of the fifty weeks per year. The quantity N is the total number of ships in the fleet and the quantity S is the maximum time available for at-sea tasking per ship, therefore the product NS is the total time for at-sea tasking for the whole fleet. In this analysis, we chose the ship-demand in such a way that:

$$\sum_{w=1}^{50} d(w) = NS$$

The demand was also fixed to be as uniform as possible (if NS is not a multiple of 50, it cannot be perfectly uniform).

24. Unlike the previous MCDV analysis, no probabilistic distribution of demand was used, nor was a Monte Carlo approach used. Each week is treated separately, and considering the many constraints, a ship schedule is constructed. For example, if the demand in week 11 was 3 ships, it would make no sense to schedule six hulls for at-sea tasking.

Scheduling Constraints

25. The set of all possible ship schedules is determined by considering all the constraints on the schedule. The constraints were determined through interviews with subject matter experts. The main constraint on the ship availability comes from the In-Service-Support-Concept (ISSC) maintenance contract. This contract specifies that each ship must be made available for a certain period of the year to the contractor. The current

requirement is 35% of the year. However, a new arrangement is currently being discussed to lower the ISSC period to 30% of the year (see Annex B), which is closer to the current practice. Based on a 50-week year, the requirement of 30% represents 15 weeks. Under the current practice, these 15 weeks are distributed in many periods over the year. Each period is usually two to six weeks long, with at least two weeks between the periods. The average duration for a maintenance period is three weeks.

26. For the study, we considered different distributions of ISSC maintenance periods throughout the year. The different options studied were[2]:

a) 5 periods of 3 weeks for each ship that is available the entire year,
    i. and two 3-week periods for the additional ship in the '5+1' option, during the half year when that ship is available for tasking;
b) One 5-week period over the summer, and two 3-week and one 4-week periods over the winter, for each ship that is available the entire year,
    i. with two 3-week periods for the additional ship in the '5+1' option, during the half year when that ship is available for tasking;
c) Three 5-week periods, for each ship that is available the entire year,
    i. with one 6-week period for the additional ship in the '5+1' option, during the half year when that ship is available for tasking.

A minimum of three weeks between each ISSC period was required. To reduce the size of the problem, each ISSC period was set to appear anywhere in nearly consecutive 12 weeks intervals. For example, the first period would appear anywhere between week 1 and 12 and the second period between week 11 and 22.

27. Other constraints on the ships' schedules are task related. Since many tasks require at least two ships, we constrained the schedules so that at least two ships are available every week. The MARS IV training for the reserve force requires two concurrent ships for 10 consecutive weeks. This training occurs twice per year on each coast. These constraints were used to determine the set of feasible ship schedules.

Optimal Schedule

28. The last step in the methodology consisted of finding an optimal ship schedule to meet the theoretical demand. This computation was done using the Lingo software (see

[2] We recall that the year was divided in two periods that we called winter and summer. Winter was fixed to be 28 weeks long and summer 22 weeks.

Annex C). This optimization method starts with a schedule and computes the quantity to minimize (the objective function) for this schedule. Then the algorithm attempts to find a new schedule leading to a smaller value of the objective function. The procedure continues until the minimum is reached. The procedure is illustrated in Table 1 assuming there are five ships. A schedule is generated for the five ships (the schedule of ship assignments to tasks), and then the supply of ships (*s(w)*) is computed for every week. This is obtained by tallying the number of ships ready for at-sea tasking. The objective function *Z*( ) is the sum, over all weeks, of the absolute value of the difference between the ship-demand and the ship-supply. The algorithm searches for the set of ship schedules that minimizes *Z*. At each step of the algorithm a new schedule is obtained by shuffling the ISSC periods of the ships. The ship-demand *d(w)* is not computed from this table; rather, it was determined as discussed earlier—leading to a fairly uniform demand across the weeks.

Table 1. Example of the optimization calculations for one possible ship schedule.

Week		1	2	3	...	50	
Ships	1	Ready	ISSC	ISSC	...	Ready	
	2	Ready	Ready	ISSC	...	Ready	
	3	ISSC	ISSC	ISSC	...	Ready	
	4	Ready	Ready	Ready	...	ISSC	
	5	Ready	Ready	Ready	...	Ready	
s(w)		4	3	2	...	4	
d(w)		4	4	3	...	4	Total
|d(w)-s(w)|		0	1	1	...	0	Z=0+1+1+...+0

29. For those familiar with optimization methods, we provide the mathematical equations applicable for the summer optimization calculation. Recall that the summer period has 22 weeks. Briefly, for five ships with two 3-week breaks of ISSC, the optimization problem is given by[3]:

$$\text{MIN } Z = \sum_{w} |d(w) - s(w)|$$

[3] As mentioned above, the set of possible ISSC breaks is restricted to a subset of the summer period (the first 12 weeks and the last 12 weeks for the first and second break, respectively). This restriction means that the obtained schedule is not necessarily optimal. But as will be discussed in Section IV, this limitation does not have an impact on the conclusion of the study.

Subject to:

$$s(w) = \begin{cases} \sum\limits_{i \notin \{w\}} \sum\limits_{j \notin \{w\}} ns(i,j) & w = 1 \\ \sum\limits_{i \notin \{w,w-1\}} \sum\limits_{j \notin \{w,w-1\}} ns(i,j) & w = 2 \\ \sum\limits_{i \notin \{w,w-1,w-2\}} \sum\limits_{j \notin \{w,w-1,w-2\}} ns(i,j) & w > 2 \end{cases}$$

-Supply of ships for week w, from generated ship schedule

$$\forall w : s(w) \geq 2$$

-At least 2 ships each week.

$$\forall (j < i + 6) : ns(i,j) = 0$$

-The 2nd ISSC period follows the 1st one by at least 6 weeks.

$$\sum_{i,j} ns(i,j) \leq 5$$

-Total of 5 ships

$$\sum_{i<4} \sum_{j>15} ns(i,j) \geq 2$$

-Two ships for MARS IV

$$ns(i,j) \in \Im$$

-The number of ships associated to each schedule is an integer.

where $d(w)$ and $s(w)$ are respectively the ship-demand and the ship-supply for the w'th week. Also, recall that $d(w)$ was chosen such that $\Sigma_w d(w) = NS$. The decision variable $ns(i,j)$ is the number of ships having their first ISSC period starting[4] on week i and their second on week j. Thus, if there are two ships that have ISSC periods beginning on weeks 1 and 8, then $ns(1,8)=2$. Hence, the number of ships available on week w is the total number of ships that are not having an ISSC period that week. Two ISSC breaks are specified, as indicated by the two indices i and j. Each break is of three weeks duration, as indicated by the i, j constrained summations (the subtraction of weeks w, $w-1$, and $w-2$ into the summation index appearing in the equation for the ship-supply, $s(w)$). The second constraint states that at least two ships must be available for at-sea tasking every week. The third one imposes that the second ISSC period follows the first one by at least six weeks (that means that the ship is available for at-sea tasking for at least three weeks between the two ISSC periods). The fourth constraint reflects that there are five ships available. The last one requires two ships to be available for MARS IV training. To reduce the complexity, we fix MARS IV training between week 6 and 15. Therefore, at least two ships must have a first ISSC starting prior to the fourth week and a second ISSC period starting after the 15th week.

[4] Two equivalent set of variables can be used to optimize Z. One set corresponds to associate to each ship a given schedule (for each ship we associate a value, for example '3', which corresponds to a given schedule – a table relating the values to the schedules has to be built). A dual approach is obtained by considering every schedule and specifying the number of ships to which that schedule is attributed. This last approach is used here since it allows a simpler expression of the different constraints.

30. The different options considered for the ships schedule are summarized in Table 2.

Table 2 Options Considered in Optimizing the Schedule of the MCDV.

Variable	Options Considered
Number of ships	5, 5+1, (i.e., 5+ one ship for half the year) 6
ISSC distribution for ships available all year	5*3 weeks, 1*5 weeks+1*4 weeks+2*3 weeks, 3*5 weeks,
ISSC distribution for ships available half of the year	2*3 weeks, 2*3 weeks, 1*6 weeks,

TASK 2 – CREW SCHEDULING

31. The demand for crews is determined from the optimal ship schedule. That is, the optimal ship schedule fixes the number of ships available each week, and the corresponding 'demand' for crews is thereby calculated so that all the available ships are manned.

32. Once the weekly demand for crews is calculated, the set of all admissible crew schedules was formed (for a given maximum number of crews). Optimization techniques were again employed to find an optimal crew schedule to meet the demand.

Number of Crews on Each Coast

33. Although there are currently five MCDV crews on each coast, options with both five and six crews were studied.

Crew Scheduling Constraints

34. There are two main requirements that constrained crew availability. First, each crew has three consecutive weeks vacation during the summer. Second, each crew has a certain amount of alongside tasks to perform over the year. Ideally, these tasks would

have a strong overlap with the ISSC periods of the ships since some duties have to be performed during this time. In the current situation, the duration of alongside tasks[5] exceeds the length of the ISSC periods. We considered three different alongside durations: 15, 10 or 5 weeks per crew, per year. These different options will allow us to determine the influence of the crew availability on the effectiveness of the multi-crewing practice. Another constraint on the crew schedule is task related: a minimum of two crews must always be available every week, and twice per year two crews must be available for 10 consecutive weeks (MARS IV training requirement).

Optimal Schedule

35. Using the set of possible schedules, the Lingo software was used to produce an optimal schedule that meets the demand as much as possible (see Annex D). The procedure is the same as the one described for the optimal ship schedule. Unfortunately, the mathematics becomes quite messy for this case, and therefore we provide enough of the mathematics to give the interested reader the objective function and constraints—for consistency with the previous optimization step. The full logical apparatus is given in the Lingo code, as mentioned. Briefly, for five crews with one 3-week leave period and five weeks of alongside tasks, the optimization problem is given by:

$$\text{MIN } Z = \sum_{w} \left| s(w) - c(w) \right|$$

Subject to:

$$c(w) = \sum_{i \neq \{w, w-1, w-2\}} \sum_{j \neq w} \sum_{k \neq w} \sum_{l \neq w} \sum_{m \neq w} \sum_{n \neq w} nc(i,j,k,l,m,n)$$

Crew availability

$$\forall w : c(w) \geq 2$$

At least two crews per week.

$$\forall i,j,k,l,m : nc(i,i,j,k,l,m) = nc(i,j,i,k,l,m) = nc(i,j,k,i,l,m) = 0$$
$$etc...$$

No overlap between leave and alongside periods

$$\sum_{i,j,k,l,m,n} nc(i,j,k,l,m,n) \leq 5$$

Total of 5 crews.

$$\sum_{i<4} \sum_{j \notin [6,15]} \sum_{k \notin [6,15]} \sum_{l \notin [6,15]} \sum_{m \notin [6,15]} \sum_{n \notin [6,15]} nc(i,j,k,l,m,n) \geq 2$$

2 crews for MARS IV

$$nc(i,j,k,l,m,n) \in \Im$$

The number of crews takes an integer value.

[5] The tasks can also vary from one crew member to another (due to individual training needs) but we do not consider the problem at this level of fidelity.

s(w) and *c(w)* are respectively the crew-demand (or ship-supply) and the crew-supply for the *w*'th week. The variable *nc(i,j,k,l,m,n)* is the number of crews having the leave period starting on week *i* and the alongside periods on week *j, k, l, m,* and *n*. There is an index for each week of alongside tasks. The various constraints impose similar conditions as we had for the ship scheduling problem. The expression $j \notin [6,15]$ is a short form for $j \notin \{x: 6 \leq x \geq 15, x \in \mathbf{I}\}$ ($\mathbf{I}$ is the set of non-negative integers).

36. The different options for the crews are summarized in Table 3. All combinations were studied.

Table 3 Options Considered in Optimizing the Schedule of the MCDV Crew.

Variable	Options Considered
Number of crews	5 or 6
Amount of alongside task/crew	5, 10 or 15 weeks

TASK 3 – IMPACT OF INEFFICIENCIES IN HULL CHANGES

37. Task 3 is composed of two main steps: (1) determine the time to conduct a hull change; and (2) evaluate the effective at-sea time for each optimal schedule obtained. The comparison of the effective at-sea time with the amount of time obtained under the current practice will then allow us to determine the effectiveness of the multi-crewing practice. T_{Tot} is the total at-sea time available (optimally), T_{Lost} is the time lost due to hull changes and T_{nMC} is the at-sea availability using today's practice of no multi-crewing, i.e., one crew – one ship. The different steps are:

1. Determine $T_{Lost.}$
2. Calculate T_{Tot} - T_{Lost} (the effective available at-sea time.).
3. Calculate T_{nMC} (the at-sea availability with no multi-crewing).
4. Compare T_{Tot} - T_{Lost} *and* $T_{nMC.}$

38. The cost in time associated with a hull change depends on many factors which may be expressed as the following questions: Is the crew coming directly from an at-sea tasking? Has the ship been inactive for a long period of time? What kind of task will the crew undertake? Has the crew done similar tasks recently? To simplify the analysis, we considered two different situations: (1) a crew going from an active ship to another active ship; and (2) a crew going from an active ship to an inactive ship. The inefficiency associated with each situation was determined from interviews with SMEs. Based on

occasional past hull changes, it was estimated that an active-to-active hull change would take at least two weeks while an active-to-inactive hull change would require one month.

39. Some SMEs estimated that a crew change could be completed in two weeks in a 'best case' scenario. However, it was also argued that the time to accomplish a crew change could be reduced if the practice became policy. Accordingly, we determined the effective time at sea for both the one and two-week cases. Table 4 summarizes the options considered for the time lost associated with a hull changes.

Table 4 Hull Change Efficiency Options.

Variable	Options Considered
Number of weeks lost for each hull changes	1 or 2 weeks

SECTION IV – RESULTS

40. For the different options considered, we determined the upper bound of the at-sea time and the lower bound on the number of hull changes. This latter value is obtained by comparing the at-sea availability for a single ship with the availability of a crew. These limits (or bounds) given here are not required for the optimization algorithm but are important for interpreting the results. It helps to understand how the total at-sea time changes between the different options. For example, for each option, it becomes easy to see which of the ship or crew availability is the most restrictive. Furthermore, since these bounds do not depend on the specific distribution of the ISSC periods or the alongside task, nor are they influence by the splitting of the year in two periods (summer and winter), they allow conclusions independent of these assumptions.

41. Table 5 and Table 6 give the upper bounds for the ship and crew availability respectively. This calculation is very simple. For example, for the (5+1) ships option, the at-sea availability is obtained from the following calculations:

a. For the ships available all year:

At-sea availability = 5 ships*(50 weeks – 15 week of ISSC) = 175 weeks

b. For the ship available half the year:

At-sea availability = 1 ship*(25 weeks – 6 weeks of ISSC) = 19 weeks,

which yields:

$$\text{Total at-sea availability} = (175 + 19) \text{ weeks} = 194 \text{ weeks}$$

A similar calculation is made for the crew availability where one has to subtract the leave time and the alongside task time from the total number of weeks (50 weeks).

Table 5 Upper Bound On Ship Availability.

	5 ships	+1 ships	6 ships
Maximum available weeks at sea:	175	194	210

Table 6 Upper Bound On Crew Availability.

	5 crews			6 crews		
	5 weeks alongside	10 weeks alongside	15 weeks alongside	5 weeks alongside	10 weeks alongside	15 weeks alongside
Maximum available weeks at sea	210	185	160	252	222	192

42. Table 7 gives the lower bound on the number of hull changes for all the options considered. These values do not take into account the different constraints on the crew and ship schedules. To compute the lower bound for the option with (5+1) ships and five crews doing five weeks of alongside tasks, we need to consider that five ships are limited to 35 weeks of at-sea tasking, one ship is limited to 19 weeks and the crews are limited to 42 weeks (50 weeks – 3 weeks of leave – 5 weeks alongside). Each crew can fulfill the full 35 weeks of at-sea tasking and can also provide an additional seven weeks of work at sea. It follows that three crews would be needed to fill up the 19 weeks on the 6th ship (3×7 = 21 weeks > 19 weeks). Thus, we deduce that there is a minimum of three hull changes if we want to maximize the at-sea availability.

Table 7. Lower bound on the number of hull changes.

# of crews	# of weeks alongside	*Minimum Number of Hull Changes Required in Schedule* 5 ships	5+1 ships	6 ships
5	5	0	3	5
5	10	0	5	5
5	15	0	0	0
6	5	0	0	0
6	10	0	0	0
6	15	5	5	0

43. Using the Lingo code, we determined a set of optimal ship and crew schedules for all the options considered. From these optimal schedules, the numbers of at-sea days and hull changes have been determined. The different results are shown in Figure 2 to Figure 5 inclusively. Each figure corresponds to a different option for the number of crews and the ISSC distribution. The three different ISSC distributions considered are numbered 1,2 and 3 as follows:

a. Distribution 1: The ISSC periods are divided in five 3-week blocks;
b. Distribution 2: One 5-week ISSC period during summer and one 4-week ISSC period + two 3-week ISSC periods during winter;
c. Distribution 3: The ISSC periods are divided in three 5-week blocks.

44. In Figure 2, the results for the different options with five crews and the ISSC distribution 1 are shown. The chart gives the total at-sea time available (in white), the effective at-sea time if one week is lost per hull change (in yellow) and the effective at-sea time if there are two weeks lost per hull change (in red). For some options, the optimal schedule does not require a hull change, therefore there are no white or yellow segments (e.g., the first four options). The blue triangles show the maximum amount of at-sea time possible assuming no multi-crewing. This quantity depends on the amount of alongside tasking required from the crews. The interpretation of the different results is thus straightforward. Consider, for example, the option with six ships and five weeks of alongside tasking per crew:

a. There is 204 weeks of total time available for at-sea tasking (T_{Tot}).
b. There is 194 weeks of effective at-sea time assuming one week is lost per hull change (T_{Tot} - T_{Lost}).

c. There is 184 weeks of effective at-sea time assuming two weeks is lost per hull change (T_{Tot} - T_{Lost})'.
d. We may want to compare this to the case where no multi-crewing is conducted. If one has 6 ships, with five crews[6], then the amount of at-sea time available with no multi-crewing is 175 weeks. The blue triangle—representing the non multi-crewing case—is therefore positioned at 175 weeks. That is:
$T_{nMC} = MIN(175, 210) = 175$
e. Result? In this case, multi-crewing "buys" the navy an extra (184-175=) 9 weeks effective time at sea, assuming two weeks per hull change.

45. Other observations follow from the results. First, for the options with five ships, we observe that decreasing the amount of alongside tasking show some increase of available time until the upper bound on the ship availability is reached (see Table 5). Once this limit is reached, there is no further gain obtained from decreasing the amount of alongside tasking. Although, it cannot be proven from the results shown here, this remark is valid for any number of ships. Second, if the amount of at-sea time is limited by the crew availability, we see that there is no gain obtained by increasing the number of available ships (e.g., compare the three options with 15 weeks of alongside tasking). Third, the effectiveness of multi-crewing can be deduced by comparing the effective at-sea time obtained with and without hull changes. The results for the options when there is no multi-crewing are shown by the blue triangles. The results indicate that the multi-crewing practice will not lead to any gain unless the time lost from a hull change is no more than one week, or the alongside tasking can be reduced to five weeks per crew per year. The most interesting gain is obtained from the option with six ships and five weeks of alongside tasking. The gain is of 5.14% and 10.9% when there are two or one week lost per hull change, respectively. Finally, the number of hull changes required for the different optimal schedules is equivalent to the minimum bound of this number (see Table 7) except for the options with the amount of alongside task reduced to five weeks per year. We can thus conclude that the effective time cannot be increased even if the assumptions on the ISSC and alongside distribution or the one on the respective length of the winter and summer periods were removed.

[6] For emphasis, if there is no multi-crewing, then each crew is dedicated to one ship, and therefore only five ships are used – regardless of which fleet option (5, "5+1", or 6 ships) is under analysis.

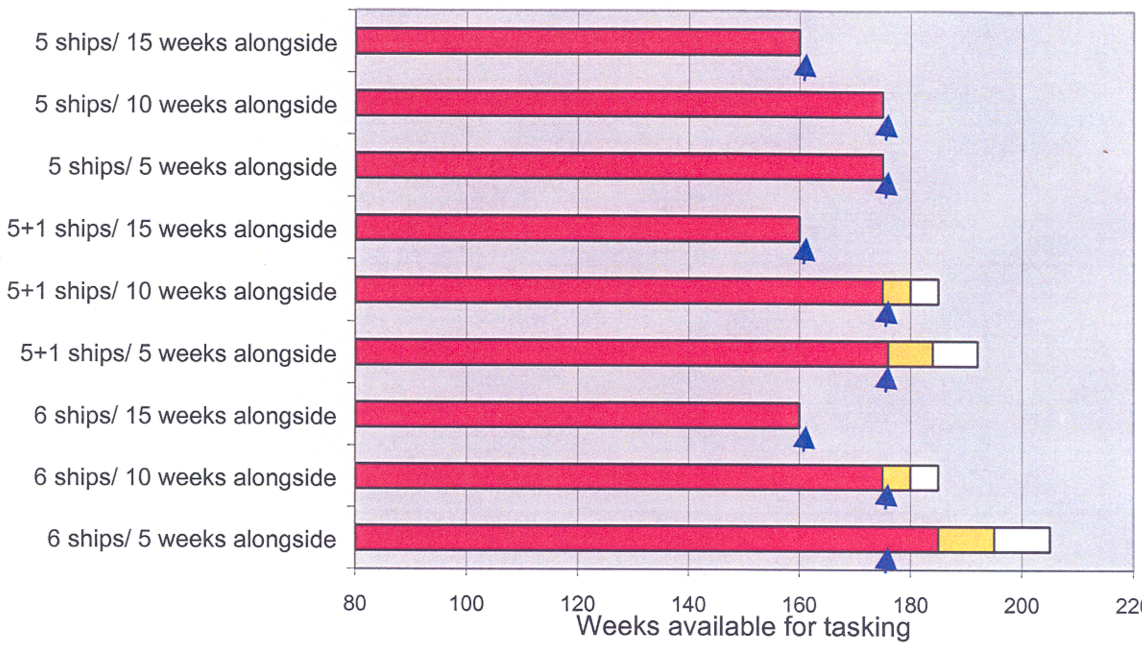


Figure 2 At-sea availability for five crews, with ships scheduled using ISSC distribution 1.

46. Figure 3 presents similar results when a total of six crews are available. The blue triangles again represent the total at-sea time available under a no multi-crewing policy (so six crews with no hull changes)[7]. The results show that most optimal schedules do not have hull changes. The option of main interest from a multi-crewing point of view is the one with 5+1 ships and 15 weeks of alongside. There are 179 weeks available for at-sea tasking under a no multi-crewing policy (blue triangle) while 182 weeks are possible with multi-crewing with two weeks lost per hull change. This means a gain of 1.68% (3/179) time at sea. Not much. Similar observations as those made in paragraph 45 holds for the six crews options results.

[7] Note that for the five ships option, we considered that the sixth crew could use one ship during the leave period of its associated crew as long as there is no hull change.

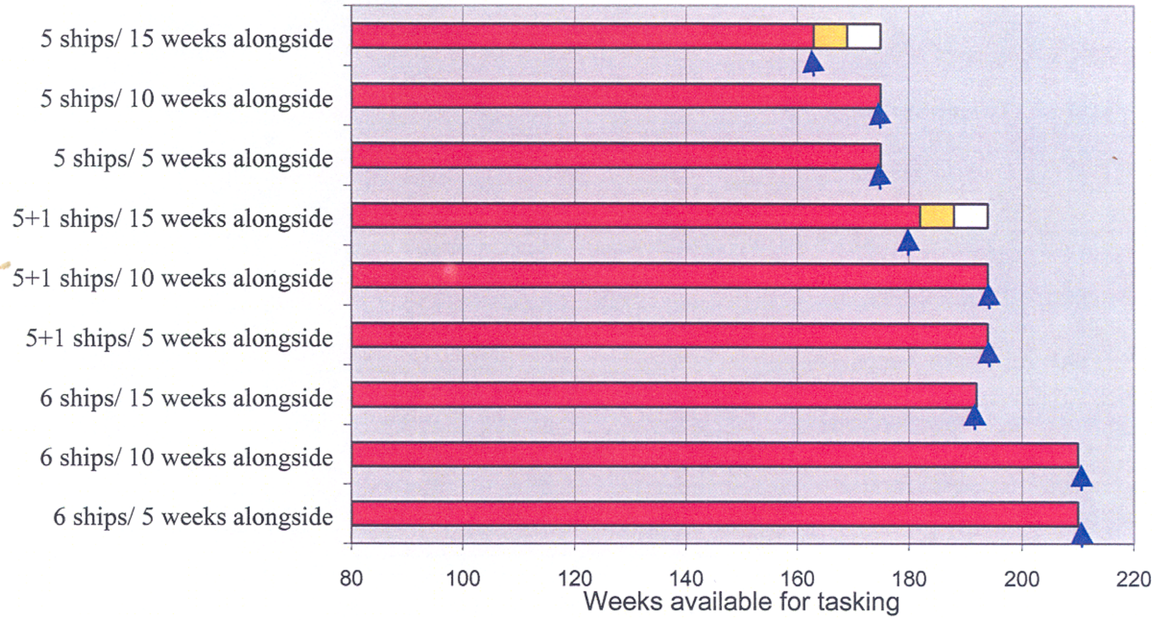


Figure 3 At-sea availability for 6 crews with ISSC distribution 1.

47. Figure 4 and Figure 5 give similar results for different distributions of ISSC. The blue triangles, indicating the no multi-crewing policy values, have been omitted, for simplicity. Comparing these results with those of the previous figures shows that the total amount of available at-sea time (T_{tot}) cannot be increased. There is little difference between the various ISSC distributions. The most important difference appears in the number of hull changes for the options with six crews performing 10 weeks of alongside and with a fleet of five or 5+1 ships. The reduction of the number of hull changes can lead to improved effectiveness of the multi-crewing practice. However, the same conclusions also apply for these different distributions of ISSC: A multi-crewing practice leads to a major gain of *effective* at-sea time only if the amount of alongside tasks can be reduced to five weeks per crew per year, or the time lost from each hull change is less than two weeks—same observation as before.

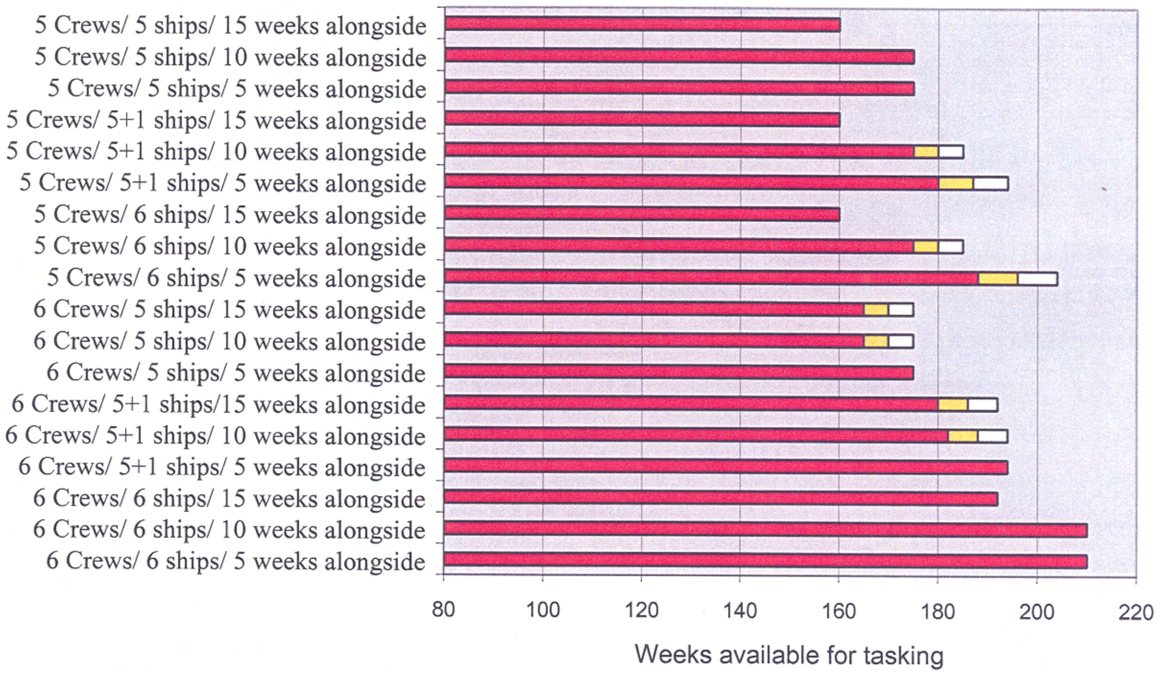


Figure 4 At-sea availability for ISSC distribution 2.

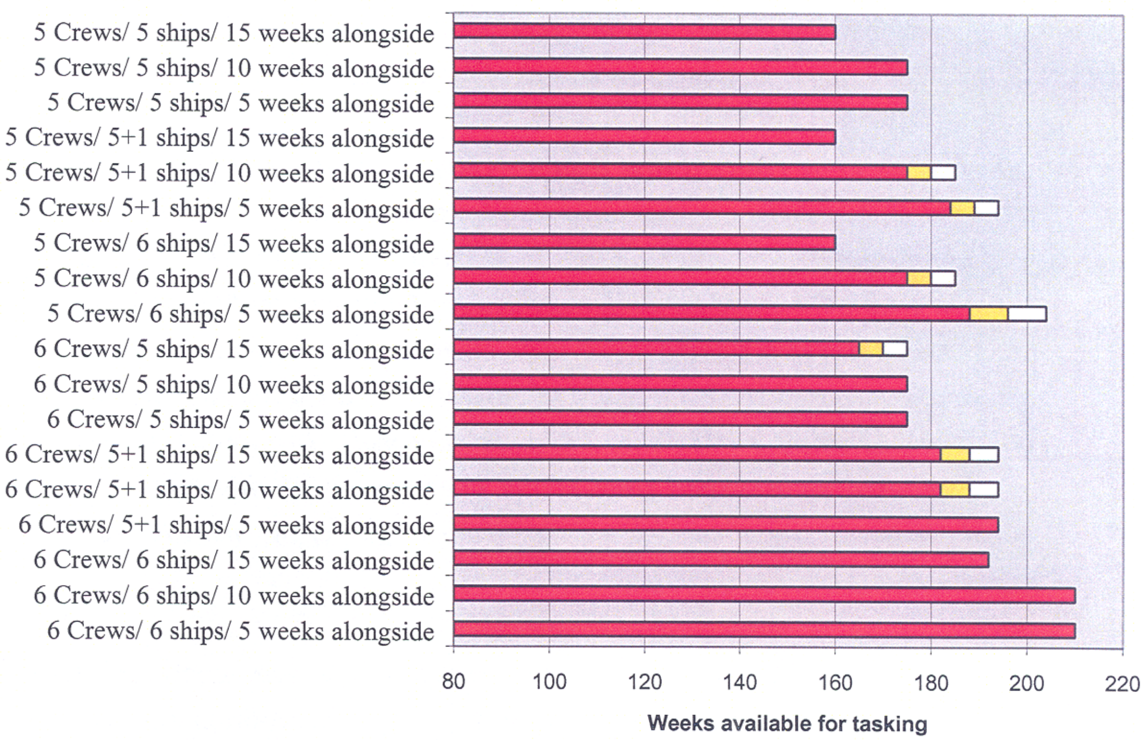


Figure 5 At-sea availability for ISSC distribution 3.

SECTION V – DISCUSSION

48. The results show that a major gain of effective at-sea time is possible only if the amount of alongside tasking for the crews is seriously reduced, and a hull change takes at most one week. Can this be accomplished? According to SMEs, each hull change currently takes at least two weeks. It is conceivable that this amount could be reduced if hull changes became a regular practice, and a program was set up to facilitate the change-over. However, the reduction of the alongside task from 15 weeks to 5 weeks seems less likely. In the current situation, some key members of the crew can barely satisfy the leave policy due to the amount of alongside tasks required. **Thus, it is unlikely that the multi-crewing practice will produce a practical gain of effective at-sea time for the MCDV fleet**. As a result, no *detailed* analysis of the consequences of a multi-crewing practice was conducted.

49. Remarks from various stakeholders on the potential consequences of multi-crewing were obtained through interviews (see Annex B). One of the concerns was that multi-crewing would necessarily increase the amount of required training (increasing the amount of alongside tasks), thereby increasing the demand on Sea Training Staff. More importantly, many interviewees opined that multi-crewing would have a negative influence on the *unit pride* and the *crew morale*. Quoting one interviewee:

> *...It also has to be realized that a ship's company in a warship develops over time an attachment to their ship that transcends the understanding of most non-seafarers, and it could be argued that this bond is the defining factor in setting the stage for high morale, esprit de corps and operational effectiveness of a ship's company. It is an emotional bond borne of a sense of belonging, shared hardship, pride of ownership and mutual support (if I look after MY ship then MY ship will look after me!). To pier-head jump crews between ships would prevent the development of this bond and would have a significant negative impact on crew morale and effectiveness.*

50. Some alternatives to increase the effective at-sea time were mentioned during the interviews. Some subject matter experts opined that improved coordination between the ship training and maintenance schedule could help the squadron meet its many obligation.

51. Some officers observed that the repetitive loop of MARS IV training wears a crew down more quickly than a diverse challenging schedule. Finally, many mentioned the used of the sixth MCDV (with a dedicated crew) as a solution for the strain on the MCDVs scheduling. In a recent report by Commanding Officer Stephan P. King [3], it was argued that this solution has many benefits including:

- More even spread of sea days;
- Better harbour and foreign port duty rotation;
- Another platform to provide training or operational support;
- Up-to-date maintenance for all the platforms;
- Greater number of qualified sailors and billets in which to put trainees.

52. In the present study, we focused on the effectiveness of the multi-crewing practice. The alternative solutions to reduce the strain have been collated in annex B, but not analyzed. However, the manning of a sixth ship on each coast was considered in a previous study [2] and it was shown that this would lead to enough at-sea time to complete the required tasks.

LIST OF REFERENCES

[1] Memorandum MS: 3700-1 (DMPOR 3-5) dated 7 December 2001, "Request for Operational Research- Investigation into multi-crewing of the MCDV".

[2] Dr P.M. Benoit and LCdr. P.L. Massel, *Availability and force employment of the Kingston class vessels*, REPORT PR2001/10.

[3] LCdr. S.P. King, *Post Deployment report on HMCS Edmonton's short period as 6th MCDV*, 2002.

Subject matter experts

This annex gives the list of the participants who generously agreed to be interviewed.

List of participants:

- Ottawa: LCdr Lorne Richardson (DMPOR 3-5).

- East Coast: Cdr Cameron (Sea Training Atlantic OIC), Cdr MacInnis (5TH MAROPSGRU HQ CCD), Cdr Newton (N31, DCOS Surface Operations), LCdr Aucoin (SSO Fleet Scheduling), LCdr Healey (5TH MAROPSGRU HQ, staff officer), Lt(N) Newell (N31, SO Fleet Scheduling), CPO2 Radimer (Sea Training Atlantic, minor WV).

- West Coast: Cdr MacNeill (MOG4 COS), Cdr Cook (CO on HMCS NANAIMO), LCdr Vasey (EO on HMCS NANAIMO), PO1 Neuman (Coxswain on HMCS NANAIMO), LCdr Turetski (CO on HMCS SASKATOON), LCdr Martin (EO on HMCS SASKATOON), CPO2 Vermette (Coxswain on HMCS SASKATOON), LCdr Ramage (CO on HMCS EDMONTON), LCdr Tucker (EO on HMCS EDMONTON), CPO2 Oliphant (Coxswain on HMCS EDMONTON), LCdr King (CO on HMCS BRANDON), CPO2 Jonhson (Coxswain on HMCS BRANDON), LCdr Gijzen (OIC MWV Sea Training), LCdr Stark.

ANNEX B
ORD PROJECT REPORT PR2003/03
MARCH, 2003

This annex reports the results of the interviews made with subject matter experts. Interviews in Ottawa and Halifax were conducted in person, while those on the west coast were conducted using email. Questions and answers are grouped according to the referred task. No attempt has been made to edit the respondents' remarks. Sometimes there are differences in opinion observed. No attempt has been made to rationalize or "average" the estimated quantities. The remarks are presented near-verbatim.

Task 1: Determine an optimal schedule of the available MCDVs to meet current demand and theoretical demands of at-sea tasking and taking into account any restrictions.

Questions will cover areas including:

1. What is the seasonal variation in the level of tasking for the MCDVs? (i.e., when are they most busy, are fewer ships in the water at some times of the year?
2. Which tasks require the same ship to be used for a consecutive period of time? How long are these periods?
3. How is the ISSC commitment met during the year? What would be the perceived ideal manner in which to meet that commitment?
4. How are workups scheduled?
5. What are the operational constraints on the ship (i.e., maximum amount of time at sea without scheduled maintenance, maximum number of days at sea per year) irrespective of the crew restrictions?

Answers to question 1: What is the seasonal variation in the level of tasking for the MCDVs?

Clearly the summer finds the ships in higher demand. There is some down time in the winter.

Peak time for operations is June, July, and September/ October (based on historical info – may be influenced by Swiss Air Disaster effort).

Nov – Jan is a real down time: Christmas effect starts in Mid December. Operations start to roll again the middle of January, and by February back to full operations. Note:
Easter weekend – ships in Halifax
March Break – Ships in Halifax

Down time seems entirely governed by QOL and holidays… it is the desire of the commanding officer for the crew to be able to have a family life.

There is not really a seasonal variation in the task load – unlike before. When the weather is bad they go somewhere where the weather is good, or they do a different task – but they still work.

The MCDV is not as weather dependent as other classes of ships.

There is only insignificant time lost to the schedule due to weather effects. It would be very safe to assume that weather did not affect availability of the MCDV fleet with respect to the amount of work that gets done.

MARS IV training requirements for the most part drive the sailing program for the MCDVs MARS IV is a 6-week program for regular Force, and is 10 weeks for the Reserve Force. Typical times are Feb/Mar/Apr, Jun/Jul/Aug and Oct/Nov/Dec for the 6 or 10 weeks required. Once the MARS training requirements are plugged into the program, everything else is planned around that requirement.

Traditionally, the summer months (June – August) were the busiest as a result of Naval Reservists availability. With a shift in training emphasis and year round MARS coursing (both Regular and Reserve) the ships are generally employed in six to ten week blocks year round. Block leave periods are assigned during the summer and Christmas (four weeks per period) where ships are alongside and not available. Five ships are generally operational (with crews), while the sixth ship is not crewed.

Depending on training requirements, the west coast ships generally follow a "trimester" style sailing schedule. The lion's share of sailing is MARS IV training, with sea phases of 6 – 10 weeks for 2 – 4 ships on average throughout the year. MARS training

commences typically mid October to mid December, mid Feb to mid April, and mid June to mid August. Generally, summers tend to be busier, as more reservists proceed to sea for their summer training. This OJT occurs most often concurrent with (or on the back of) MARS training, though specific ships may be tasked with OJT only.

There is not a substantial difference in operational tempo from winter to summer. This is in fact the first year MCDVs on the west coast have been made available for other missions other than the completion of MARS IV training during the summer months.

Answers to question 2: Which tasks require the same ship to be used for a consecutive period of time?

NATO exercises: Blue Game occurs every second year and requires the participation of 2 MCDVs.

MARS IV Training requires that each student receives a certain amount of bridge time. Accordingly, the number of students defines the number of sea days required for the course. At least two ships are required in order to conduct this training course.

For MARS IV training, the students could conceivably swap ships in the middle of their course as far as course content and syllabus and evaluation of their skills is concerned. However, even at best this swap of ships is going to take 2 weeks – causing the course to be 2 weeks longer – not really advisable as far as adding time to the training load of both the students and the fleet. Also, we are not even sure how adding 2 weeks to the length of the training course would effect the overall operation of the "school". Therefore, it is advisable to keep the students on one ship for the duration of the course – also **do not** change the CO of the ship in the middle of the course.

Back to MARS IV – the reason for doing more than one ship consecutively is to practice manoeuvres – note that this is no longer listed as a requirement in the syllabus for the course. There are definitely benefits to be gained from being able to do this as part of the course – but it is not required – so list this as a "Desired but not required" outcome.

NOTE: The MCDV is never deployed outside Canada alone… it is always accompanied by at least one other ship – so usually 2 MCDVs are deployed when they go somewhere – this will be important in the set up of the model.

If a ship is to be tasked with payload operations, it (the crew) must undergo payload training (about a month), followed by WUPs (another month). The ship would normally deploy for an exercise for one to two months. This would be accompanied by about a week of pre/post deployment leave. This activity involves typically two MCDV per coast per year. Typically the two ships per coast conducting payload work do so for 50 sea days/year (total, not each – this may increase shortly due to homeland defence issues).

If ships have embarked payloads they generally maintain that mission for a period of 18 months to two years. The rationale is the specific specialized training that is received by the crew.

There appears to be a tendency for certain ships to conduct continuous MARS training, while others receive payloads. There are pros and cons to this, notably that while keeping a ship in a continuous employment area builds expertise, it does not effectively balance or spread that expertise amongst the other units. Additionally, some ships are regularly involved in operational exercises with multinational, foreign deployment, when others routinely stay behind. This has a deleterious effect on morale.

Although it has been proven that students can perform a hull transfer in mid-MARS IV training, it did create a level of frustration for the students and additional distractions, hindering the progress of the students for at least four training days. A MARS IV course Reserve is 10 weeks.

Answers to question 3: How is the ISSC commitment met during the year?

Two weeks is a good assumption for the minimum length of the ISSC

Max time required for ISSC: every one year = 4 ISSC blocks. One big block in summer, includes upper deck work not able to be done in poor weather conditions of the winter.

ISSC periods: At least two 3 weeks sessions, others are 2 weeks
Who is on board during the ISSC: a duty watch of 3 people, staff to support the ISSC (2 people). Note: any one of the engineers can support the ISSC (1 of 4 people) it does not need to be the chief.

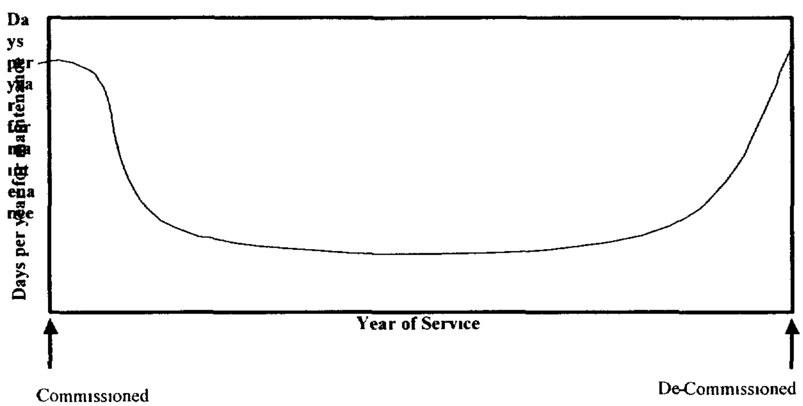
There is a draft revision to the ISSC contract right now: the availability requirement would be reduced to 30% of the year.

Not all maintenance is in the ISSC contract… there is unscheduled maintenance that can take place, some of which is outside the time set aside for ISSC.

Planned maintenance routines (Docking period) are conducted every five years. They are four to eight weeks long (include a hull inspection, etc.). The total time that it is unavailable to the schedule is about 25 weeks (includes docking and trials) – this period must then be followed by full workups.

The ship that is rotated in and out of extended readiness requires this same 25 weeks + w/ups… i.e., is unavailable for ½ the year!

Profile of maintenance requirements for an MCDV:



A typical ISSC plan, based on past history, for an MCDV over the year would be:

a. Mid/end December: Ship is not available, crew on leave;
b. January: Ship available for ISSC, crew also undertaking refresher training;
c. February to mid-April: Ship engaged in MARS training, surveillance/SAR (Search and Rescue) patrols, payload work/exercises. Payload work is not compatible with MARS training, there are no bunks for students;
d. Mid-April to end of May: Community Relations taskings, work-ups (WUP). If not sailing then ISSC;
e. June to end of July or mid-August: Sail for MARS IV training or exercise requirements;
f. August: Once MARS training or exercise requirements are met then crew goes on leave for 3 weeks summer leave (mandated by CMS). Normally, no ISSC work can be conducted concurrent with a leave period since a security watch must be on each ship with contractors on board. Ships stand nested security watches, ie: for a nest of three ships there is only one security watch during a leave period – this precludes any ISSC work;
g. September: ISSC period, concurrent crew undergoes refresher training and prepares ship to sail in October; and

h. October to mid-December: Ships sail for MARS IV, payload work and Naval Reserve Division Training (around a total of 40 sea days per year)
i. Go back to 'a' above.

At present, ISSC runs their repair and maintenance schedule around the ship's sailing schedule for dedicated ISSC periods. These can and are often shuffled around, and ISSC has to be informed, otherwise they will be paid regardless of whether the work was done.

Additionally, ISSC can deploy or arrange for contract work to occur when ships are deployed. In my experience, the Navy has benefited greatly from this form of systems management. I have yet find fault with the services provided by ISSC. Indeed, there are many examples where this method has resulted in exceptionally efficient, cost-effective resolutions to engineering problems.

The only recommendation I have is that we as the customer have the foresight to inform our service provider (ISSC) immediately or as soon as practicable if our schedule interferes with their work plan. Otherwise, I see little re-working required to satisfy any ISSC concerns.

ISSC periods often conflict with leave periods. The OPSKED (Operational Schedule) fails to allow ships an opportunity to piece a ship back together and prepare the crew for sea. The MARPAC leave policy and the ISSC and operational commitments make it extremely difficult for persons who are key to the repairs and maintenance to comply with the policy. Leave periods conflict with ISSC, and whenever a ship is alongside the ISSC staff embark to conduct repairs or maintenance. There must be three distinct periods alongside;

a. ISSC maintenance and repair;
b. Annual Leave period (two/three week windows)
c. Training (two ships at a time/two week periods).

Answers to question 4: How are workups scheduled?

In cooperation with the staffs of CMOG4/5, MARPAC/LANT N3 and Commander Sea Training, each ship is scheduled for any required WUP, DWUP, MWUP or AWUP (Work-ups, Directed Work-ups, Mechanical Work-ups or Assisted Work-Ups). At least once every two years each ship must undergo a full WUP of about a month. If a payload is embarked on a ship (one to two ships per year) then the ship must undergo a MWUP. If a Commanding Officer (CO) feels his team has a shortfall in performance (ie: damage

control, blind pilotage) then he/she may request an assisted WUP (AWUP) which takes about 3 days. AWUPs are relatively rare, maybe one ship per year. If there is a major change in the Command Team out of cycle with the biennial WUP program or if there is a hull change, then the ship will be required to undergo a DWUP – about 3 days.

Workups are scheduled once every 18 months – however there may be workups required if there is a significant turnover in the crew – these would be directed workups (directed by the commander).

WUPS – crew must be certified every 18 months
Each time on a new ship requires a ship readiness inspection.
Payload workups: crew must be certified to use the equipment: 1-2 weeks (plus loading the payload on the ship)

Important point:
Route Survey (RS), Mechanical Mine Sweep (MMS), BOIV are payloads that would be best served if the crews were always working those specific payloads.
It takes 2 weeks to have the payload fitted then an additional 2-3 weeks to **certify** the crew.
Full workups (3 weeks long): the last week of this wups requires a second ship be around (not in workups) to use as a "test" for the equipment, etc.

Team Mine-sweep requires two ships (ideally, all MS should use two ships).

Two days of the directed workups requires two ships (one not in wups).

Full workups require 17-21 days (followed by 3 days rest).
(Note, East coast failure rate on wups is about 5%, a redo of workups usually takes two weeks).

Full workups are required every 18 months, and during every RSP (readiness Sustainment Program).

Directed workups usually take two weeks (though they have been as short as one week). Can be requested by the commander at any time.

(Note: workups scheduled for two weeks once every two years would probably be perfect, and may eliminate the need for directed workups!)

Mission payload – if on an otherwise worked-up ship, 3-5 additional days are required.
Exceptions: MMS -> 2 weeks (safe to sail = 1 week, safe to operate = 1 week)
RS – one additional week

Workups are scheduled around the operational cycle of the ship. With the MCDVs this should roughly follow a two year cycle of Ship Readiness Inspections (SRIs) followed by a three week Standard Readiness Workup. Ships embarking any of the containerized systems (e.g., Route Survey, Mine Sweeping, etc.) would require further Workups varying between two and ten days depending on the package.

Workups should be scheduled whenever a significant portion of the crew changes over, especially in senior positions. Additionally, Work Ups (WUPS) should occur as close to annually as possible. Directed WUPS will occur when a payload, mission, or other factor requires that a specific component of the ship/crew be brought up to the required Fleet standard before commencing specific operations or missions. Lastly, if a CO feels that there is some risk or degradation in the competence of any area within the ship, a WUPS can be organized to identify and correct the deficiency.

There are often over-riding factors that preclude WUPS. These most often are due to scheduling conflicts, where too many demands are placed on either the Sea Training Staff or the Ships, or both.

For the most part work-ups seem to be scheduled through crisis management. Timings selected never take into consideration the "near future" crew transitions. Ships are often completing WUPs when within a month 30-50% of crew are scheduled to turnover.

Answers to question 5: What are the operational constraints on the ship?

As far as how long it can work continuously, or the wear and tear on the ship from working too hard, it may be more important to discuss the length of time the ship is operating under given weather conditions rather than just the amount of time at sea.

Restrictions on continuous operation: the only restriction noted was on food and ration stores (approximately 18 days worth without reloading). But food and rations can be replenished in a different port… so is it really a restriction?

72 days is the longest deployment (Europe for Blue Game). The average deployment is 3 weeks.

Through my experiences on HMCS NANAIMO when she first came to Victoria, we experienced an intensive sailing schedule just below 200 days. Although busy, the crew found the missions to be challenging and diverse. If programs remain flexible and don't place ships into a repetitive loop of MARS IV training, sea days can be increased. The demands and repetition of MARS IV training wears a crew down quicker than a diverse challenging schedule. 180 days at sea is a good base line.

There is any number of operational constraints, but the greatest are provisions (food stores) and an unreliable engineering plant. Approximately 14 days is a reasonably reliable length of time for continuous steaming. If the fridges were more efficiently laid out (more storage) and if the engines and propulsion system were made more reliable, it is reasonable to assume that the ships could remain at sea for up to a month. Storage for fuel, water and dry goods is ample.

When scheduling total sea days, the ship's programme throughout the year needs to be taken into account. It would be reasonable to allot 180 sea days per ship, per year. This would allow for annual leave, maintenance, and should accomplish training and operational goals.

The maximum sea days are set at between 100 and 120 per year. This allows for the required contractual availability for the ISSC contract, crew rest and coursing.

There is no specified maximum period between ISSC periods, but historically it has never been longer than 3 months, nor should it be any longer. CMS has mandated 600 sea days per coast for the MCDV fleet or 120 sea days per ship if 5 are running on each coast.

Task 2: Based upon the schedule of the MCDVs as determined in Task 1, construct a crew schedule to optimise the crew/ship availability.

Questions will cover areas including:

1. What is the seasonal variation in crew leave? How much time is required to ensure the whole crew gets leave?

2. What are the required alongside tasks? How much time do they take? Are there any policy requirements for these tasks - or are these tasks assigned because the crew is along side?

Answers to question 1: What is the seasonal variation in crew leave?

Leave allocation for Reserve forces: 2 days per month = 24 days in the year. Attempts are made for the majority of the crew to take leave at the same time.

May – September: 3 weeks blocked for leave to accommodate 2 weeks of crew leave.
Christmas: 3 weeks of calendar time to accommodate one week of crew leave.

Designated leave in the summer: >= 2 weeks… they are being blocked in 4 weeks to accomplish the 2 weeks for everyone. 3 weeks are blocked out in the Christmas period.

Assuming the crew is still standing home port security watches, it would take a month in the summer and a month in the winter to cover off required leave. Without security watch requirements, this would be about halved. It is doubtful the command would approve ships to be left with no security watch, there would be too much risk to the ships. Seasonal variation – almost all leave is taken in July, August and December. Additional comments may be found at assumptions above. Essentially the ratio of time to leave is 2/3, i.e.: for every three weeks designated for a Ship an average crewmember can take approximately two weeks. This varies with nest configuration and alongside requirements/tasks.

The ship required two block leave period that should be five weeks each in length. This allows for the 24 days of leave that each crew's member is generally entitled to. Additional time alongside is required pre and post deployment to allow for pre and post deployment leave which is separate than annual leave.

All crew are entitled to leave based on their contract length. For those on year long or greater contracts, they receive 24 days of annual leave, in addition to statutory holidays and special leave. Three specific leave blocks are set aside each year (Winter/Spring/Summer). Problems occur when people move about from ship to ship without taking their annual leave.

A minimum of two leave periods, Christmas and Summer, are essential. The timings must correlate with a portion of the public school vacation periods to allow parents an opportunity to spend quality time with their families. A third leave period for a lesser

time period of two weeks prior to the end of fiscal year would also permit units to comply fully with the MARPAC Leave policy.

Answers to question 2: What are the required alongside tasks?

Alongside tasks: The calculation of the tasks required of CFCD 102 alone would be about 200% of the alongside and at-sea time...

Alongside tasks > ISSC time
Includes courses, administration, environmental requirements, disciplinary processes, etc.

Alongside training includes individual skills, group skills, team skills. (School, primary training, trades training), alongside tasks include (in addition to this training) engineering tasks, duty watch, environmental, safety and harassment training. Many officers have formal training requirements. Note that the 32 people on the MCDV have all the same responsibilities as the 32 people with the equivalent jobs on a big ship (but on the big ship they are only 1/10 of the whole crew... here they are 100% of the crew!). Additional alongside tasks include administration (policy requirements), ship readiness inspections, audits, and simple management tasks (plus incremental tasks like tours, hosting receptions, etc.)

One month to six weeks of alongside crew training is required.

There is quite an extensive list of refresher and specialist training ships personnel are required to take over the course of a year. How much time do they take? As a general rule it takes about a month to a month and a half (with payload training) to accomplish this training. Are there any policy requirements for these tasks - or are these tasks assigned because the crew is alongside? The training is mandated by CF and Maritime Command orders and directives ie: CMS through MARCORDS and Ships Standing Orders to ensure individuals and crew teams are trained and competent in their duties. None of this training is 'make work', it is required training. This training includes: Sea Survival, First Aid, Advanced First Aid, Small Arms, Fire Fighting & Damage Control, Fire Leader, Flood Refresher, Section Base Training, Section Base Team Training (Entire Ship at once), Nuclear Biological Chemical (NBC), Express Testing (Fitness), Blind Pilotage, Payload Training, etc.

There are a significant number of additional tasks that require alongside time: individual and team refresher training (eg: DC, FF, Hazmat, General Safety, First Aid, Small arms),

inspections (e.g.: NPF, PF, Hazmat, General Safety, CSD, Comsec, Radhaz, Navigation) engineering periodic maintenance. These required taskings will require at the least one day for some of the refresher training and inspections, to several weeks (i.e., at least three) when considering engineering.

Interesting question. When ships are alongside for extended periods, they are generally under-going maintenance, during which time annual leave and career coursing can be taken. As is often the case, the ships are prime targets of opportunity for various initiatives by other agencies to conduct alongside training. There is a varying degree of planning, organization and heads-up that occurs for these events (from none-at-all to very-well-prepared). The length of time each task takes is as varied as the tasks themselves. They can include: ship tours (civilian or military); payload coursing for Route Survey, WDO, BOIV, CDS; support to Fleet Schools and NRDs; the list is endless.

In addition to events occurring on board, the ships are regularly tasked as manning pools to support shore agencies. Parades, Fleet School, NABS support, crew manning for other ships – virtually any conceivable event or tasking can and has been asked of MCDV crews. This is likely no different from the major warships, as the Navy struggles to meet demands.

When the ship and outside agencies coordinate well, the results are fruitful and provide the best training possible without going to sea. In other cases, it causes frustration and resentment, as the ship is left to scramble to meet obligations with only minimum notice. Too often, members of the ship's company are required to bend, which ultimately impacts on their desire to stay employed in a certain ship or within the reserve. This comment is not under-stated, especially when taken in context with other MCDV and reserve-specific issues.

Ship's maintenance and refresher training are key elements to alongside activities. Trade training as well as environmental, safety, documentation/security courses, harassment coursing, and personal development courses fill much of the time alongside. Ships are already hard pressed to fill all the training requirements into the time provided when alongside. This is not solely attributed to the lack of time provided alongside, but the lack of coordination, or willingness to coordinate through OPSKED planning and school availability. If hard timings could be identified both through the DC school and MOG staff i.e.: two-week windows which two ships are made available for training. While one ship trains the first week, the other ship mans the harbour watches.

Task 3: Once a ship and crew schedule has been determined, the impact of changing crews (multi-crewing) will be calculated. The residual available time will be compared to that available in the current schedule as a measure of the effectiveness of the new approach.

Questions will cover areas including:

1. What would be the cost (in days) of doing a crew change on an MCDV in various different situations (i.e., active crew to active crew, active crew to crew coming off leave, etc.)
2. Would doing a change of crew effect the requirements for workups?

Answers to question 1: What would be the cost (in days) of doing a crew change on an MCDV?

From recent experience with WHITEHORSE crew shifting to EDMONTON, one month was needed to effect the physical shift of the crew to the second ship, securing the departing ship and standing up the arriving ship. The ship's Distribution Accounts have to be sorted out and missing items procured, Classified Standard Documents & COMSEC need to be properly accounted for and turned over, chart & navigation outfits need to be regenerated, ship's systems need to be proven, etc. If the ship has been in an extended work period, then at least a week of sea trials are also required to ensure all ship's systems work, followed by SRIs and WUPs.

I have experience in dealing with a crew change from an active ship (HMCS WHITEHORSE) to an inactive ship – to subsequently activate – (HMCS EDMONTON). The process took approx 45 days once the document supporting and authorizing the hull change was released.

I have been involved directly in five hull changes or deactivation/activation of MCDVs. Each case is different, involving various degrees of preparation. On average, 14 days is required to do a full hull transfer between active hulls. Only 4 days are required to physically transfer materiel; the greater requirement is the notification of all shore agencies to arrange fuel/ammo/CSDs/COMSEC/NPF and the plethora of administrative nausea that occurs.

Based on my experience with a hull transfer from BRANDON to EDMONTON and then back to BRANDON, it would take any where from two to three weeks to complete a

crew transfer. Distributed accounts and transfer of NPF accounts alone take one week to complete.

Answers to question 2: Would doing a change of crew effect the requirements for workups?

If it is a crew that has been worked up recently (i.e.: in the last year) then only a DWUP or SRI (Sea Readiness Inspection) would be required: 3-5 days. If it is not a worked up crew, then an SRI (3 days) followed by a WUP (one month).

Some form of workups would be required. In the case above the readiness of the ship was examined as part of a Sea Readiness Inspection Program. This is due to EDMONTON not having been crewed or underway for a period of time.
Doing a change of crew would require that crew conduct the entire SRI/Workup cycle, therefore, in effect, doubling the time required for Workups for the ship. Ships also need time to prepare for Workups, ideally two to three weeks and this needs to be added into the equation.

Other training concerns would include that the amount of refresher training required would in effect double for the MCDVs. This must be taken into account as the refresher training system is already overburdened and ships cannot get what they need. The requirements for weapons certification would double. Other issues include the requirements for formation inspections as a major part of many inspections are personnel (e.g. how many are environment trained/HAZMAT trained etc.). Other training issues include HAZMAT, burning and welding, environmental etc, etc (the list is a long one).

I would not feel comfortable (nor, I suspect, would the Admiral) going to sea with an untested, unfamiliar and most likely "green" crew. There are Sea Readiness Inspections (SRI), refresher training, appointments of custodians, and a host of other requirements to get a ship and her crew up to a safe operational standard.

The requirement for WUPs would be a must. Having a crew idle and inactive quickly causes rust to accumulate where skill sets of the crew are concerned. The re-familiarization required to become operational within a ship is key. WUPs bring a crew quickly into a cohesive team refocused on the task at hand (going to sea).

If available at-sea time sufficiently exceeds that currently available, then the project will proceed to a fourth task.

Task 4: Investigate the consequences of making such a change to scheduling practices, i.e., Implications to infrastructure, training and certification, maintenance policies, crew cohesion, etc.

Questions will cover areas including:

1. What are the Quality of Life issues that are mandated by policy?
2. What are the Quality of Life issues that are preferred to be maintained where possible?
3. Are there any anticipated concerns in training, cohesion, infrastructure, etc. when considering doing crew changes with the MCDV?

Answers:

There is already a lot of micro level crew swapping happening with the comings and goings of the reserve members – there is a concern that overlaying a macro swapping to this will create a sense of chaos.

It is an immense amount of work to shift crews between ships accompanied by a significant cost in sea days and local procurement costs. Also, the crews of the KINGSTON class are well attached to their namesake cities and identify strongly with them through cooperative namesake city activities and support of charities in namesake communities. To be constantly shifting crews between ships would not only affect cohesion because of the inevitable personnel changes, there would be a deleterious effect on morale due to the added workload of the shift, trials and WUP requirements. Each hull change would take a ship/crew out of circulation/mission availability for one to two months. It also has to be realized that a ship's company in a warship develops over time an attachment to their ship that transcends the understanding of most non-seafarers and it could be argued that this bond is the defining factor in setting the stage for high morale, esprit de corps and operational effectiveness of a ship's company. It is an emotional bond borne of a sense of belonging, shared hardship, pride of ownership and mutual support (if I look after MY ship then MY ship will look after me!). To pier-head jump crews between ships would prevent the development of this bond and would have a significant negative impact on crew morale and effectiveness.

The fact that multi-crewing would also double the work of Sea Training staff cannot be overlooked. Would the plan include augmenting them as well?

Crew changes have been found to be unsatisfactory on several levels. A ship takes on the persona of her ship's company, and sailors feel very attached to the ship they spend so much time caring for and living in, and they bond closely with the city the ship is named

after. Sailors also develop close relationships with their peers. It takes months for this feeling to diminish, and yet many still feel a desire to return to "their" ship.

The Naval Reserves have been challenged to meet the requirements as to maintain operational ships when required. Only through the use of other unit's personnel, has MOG Four and CANFLT PAC been successful putting MCDVs to sea when required. This consistent movement of personnel from ship to ship has significantly reduced the quality of life on the MCDVs for personnel in key trades. An attempt to develop two distinct crews will further diminish the quality of life by requiring personnel to backfill positions and be called upon to complete two complete periods within the ship affected by the crew change. The difficulties the MCDVs, and the Naval Reserves have experienced when attempting to man the ships with one crew each only lends credence to my statement regarding the further demise of quality of life.

A large part of a ship's cohesiveness and moral is unit pride. Moving crews from ship to ship every six months or so would negate the opportunity for both Namesake city liaison and unit pride to develop. If training is scheduled just prior to crew changes training planning and scheduling would be made easier than it currently is.

Additional remarks:

Three key important points: utilization of the 6th hull, utilization of leave, and defining and prioritizing. Effectiveness **not** efficiency when it comes to scheduling the MCDV... The MCDV is, ultimately, an operational ship, not a training ship, and must be available for operations – which are ultimately unpredictable and random.

Question: What is the critical size/ capability/ complexity level that creates a critical point at which the hull changes are beneficial? Clearly they worked on the patrol boats. Is there some level after which they will not work? Are the MCDVs at or beyond that level?

For examples of hull transfers and crew/ ship independence, look to the British and the Dutch – as they believe they are doing something similar in some of their smaller ships.

I don't see there is a possibility to have spare crews waiting to exchange with one another so that other ships get rest. It would be far more beneficial (in my opinion) to activate the sixth MCDV, thus sharing the sailing load amongst 6 ships. Having Captained the sixth MCDV, I can state from my own experience that it was well worth the cost, and did what it set out to do – train NRDs (thus motivating Class A reservists) OJT training at sea, requalifying several members in all trades.

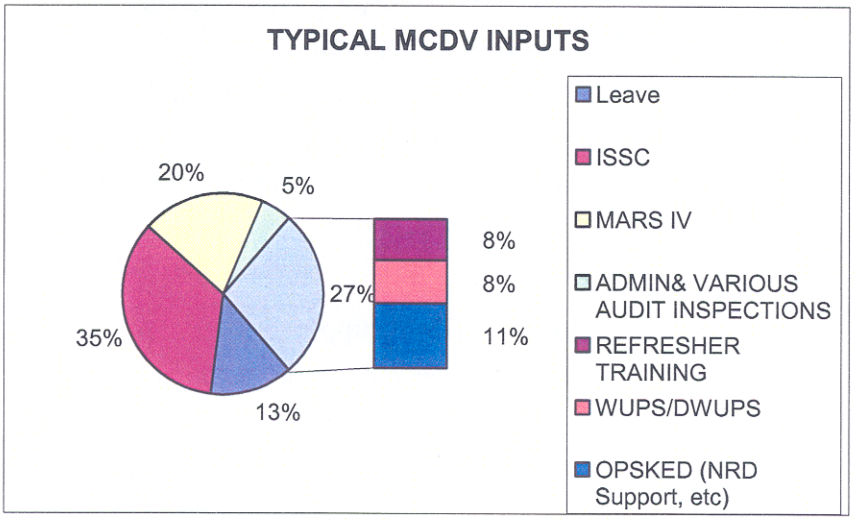
I consider this initiative was one of the most successful examples of implementing a concept that went "outside the box". I completed a detailed post deployment report, which endeavoured to capture the successes, failures, costs, timings etc. Perhaps this would be of some use for this study. I feel strongly that having six ships on the water, actively engaged in operations and training, is the best use of present resources. While it takes some flexibility and imagination to get the ship operational, the benefits include:

- More even spread of sea days
- Better harbour and foreign port duty rotation
- Another platform to provide training or operational support
- Up-to-date maintenance. Ships, like vehicles, are more reliable when used regularly. EDM was in rough shape when she was reactivated
- Initially it was difficult to accept that there were enough crew to man the sixth ship. There were immediate benefits from activating this hull. After a short period of time, dividends become apparent, including a greater number of qualified sailors, and billets in which to put trainees

There are many challenges faced by the MCDVs. They range from the boredom of repetitive sailing or alongside periods, to the operational challenges of accomplishing missions which test the limits of reserve training. I believe the average full or part time reserve sailor meets these challenges with vigour and determination. This is evidenced by the fact that we have been continuously undermanned, paid less (overall) than the regular navy, and have been regularly tasked with accomplishing our tasks under a constant change of schedule.

The proposed study framework, which "aims to investigate the impact on at-sea time when ships have multiple crews in the course of a year," needs further considerable refinement. The proposal may have merit, but due to the overall structure and fluidity of MCDV manning by Naval Reservists, any further elements that may directly or indirectly affect crew cohesiveness, corporate knowledge, quality of life or morale, could make an already tenuous situation untenable, given current conditions and constraints. However, if a variant of the American "Blue/Gold Crews," six-month rotation model was considered, with a fully funded and manned shore office, then crew composition, effectiveness and morale could be maintained – *as long as crews rotated in and out of the same ship and were not shifted between ships.*

First, the chart below highlights some of the demands/inputs placed on MCDVs in a 365-day year. It is obvious that the demands are high and the management complex.



Ship's Companies typically log in an insurmountable amount of "over time" at sea, daily & weekends, and ISSC is hard pressed to achieve the 30% target within the current parameters. Specifically, the assumption of a 5-day – 37.5 hour "public service work week," clearly does not apply to the Navy, due to duty watch, overtime, and a 24 hour/7day at sea working requirement. Furthermore, the 120 sea days per ship assumption in this proposal does not account for the total days away from homeport. Which is to say that, there is an inordinate amount of inputs and demands that are not accounted for, that when further exacerbated by rotating hulls within the existing structure, would make this concept inoperable. It's obvious that the authors must flesh out further detail with examples and hypothesis of working "Rotating Crew" concepts or models, to guide this study to a workable end.

Pay issue. About 29 of the 40-person crew receive Class C (regular force) pay. Some of the 29 do not receive PLD, which in Victoria exceeds $650/month. Depending on your position, you might be paid a Lt(N) or MS salary even though you may be a LCdr or PO2 or above. This pay inequity is confusing, biased and preys heavily on the QOL of all sailors. Generally, everyone feels the amount of pay is acceptable. The disparagement occurs due to the great variance of rates and entitlements. Of all the issues noted about QOL in multi crewing an MCDV, they all pale in comparison to the pay issue.

ANNEX C
ORD PROJECT REPORT PR2003/03
MARCH, 2003

CODES FOR THE SHIP SCHEDULES

Lingo codes has the following structure:

a. defining the sets;
b. the objective function; and,
c. the constraints.

Every comment in the code starts with an exclamation mark, and finishes with a semi-colon. Every internal function starts with an @ symbol. We used the SUM, ABS, FOR and GIN functions that define the sum over a set, give the absolute value of its argument, define a loop operation and impose the integral constraints, respectively.

CODE FOR THE SHIPS DURING THE SUMMER PERIOD

```
! Scheduling problem for MCDV, ship schedule;
! The year is split in 2 blocks. This is summer;
! The variables used are the weekly demand (d(w)), the number of ships available;
!  weekly (s(w)) and the number of ships having their ISSC breaks starting on weeks;
!  i and j (nbs(i,j)). s(w) is computed from nbs(i,j). d(w) is fixed from a set of data.
! Defining the sets. WW is the set of weeks. We chose summer to have 22 weeks;
! II and JJ are respectively the set of first and second ISSC break;
! For example, i=1 corresponds to a ISSC break starting on the first week;
SETS:
  WW / 1..22 / : d, s; ! The set of weeks. Two variables are defined over this set d and s;
  II / 1..12 / ; ! The set of all possible first ISSC break;
  JJ / 1..12 / ; ! The set of all possible second ISSC break;
  XX( II, JJ) : nbs; ! The set of all possible schedules. The variable nbs is defined over;
!  this set;
ENDSETS
! Objective function: The sum over all weeks of the difference between the demand and;
! the number of ships available;
 MIN = @SUM( WW : @ABS(d-s));
! Supply of ships for week w (s(w)) from generated ship schedule (nbs(i,j));
! The ISSC breaks (i and j) are chosen to start in the intervals [1,12];
! and [9, 20] respectively;
! The sum is over the subset of XX that satisfy the logical constraints express after;
! the vertical line (|);
@FOR( WW(w): s(w) = @SUM( XX(i,j) | (i #GE# w+1) #OR#
                ((i #LE# w-3) #AND# (j #GE# w-7)) #OR#
                (j #LE# w-11) : nbs(i,j)));
!Constraint on the number of ships available each week;
@FOR( WW : s >= 2);
! Constraint due to the fact that further break must follow previous one;
```

```
! by at least 6 weeks;
@FOR( XX(i,j) | (j #LE# i-3) : nbs(i,j) = 0 );
!Constraint on total number of ships available;
@SUM( XX : nbs) <= 5;
! Imposing at least 2 ships available for 10 consecutives weeks from the sixth;
! to the fifteenth week (MARS IV);
@SUM( XX(i,j) | ((i #LE# 3) #AND# (j #GE# 5)) : nbs(i,j) ) >= 2;
! Fixing the demand;
@FOR( WW(w) | (w #LE# 14) : d(w) = 4);
@FOR( WW(w) | (w #GE# 15) : d(w) = 3);
! Constraint of integer values;
@FOR( XX : @GIN( nbs));
END
```

CODE FOR THE SHIPS DURING THE WINTER PERIOD

```
! Scheduling problem for MCDV, ship schedule;
! The year is split in 2 blocks. This is winter;
SETS:
  WW / 1..28 / : d, s; ! 28 operating weeks: Demand, ships available;
  II / 1..9 / ; ! 9 possible first 3 weeks break;
  JJ / 1..9 / ; ! 9 possible second 3 weeks break;
  KK / 1..9 / ; ! 9 possible third 3 weeks break;
  XX( II, JJ, KK) : nbs; ! nb of ships with break starting on weeks ii, jj, and kk;
ENDSETS
! Objective function: demand for ships - ships available;
 MIN = @SUM( WW : @ABS(d-s));
! Computation of the total number of ships available each week;
! The breaks are respectively scheduled in the intervals [1,9];
! [9, 17] and [18, 26];
@FOR( WW(w): s(w) = @SUM( XX(i,j,k) | (i #GE# w+1) #OR#
                ((i #LE# w-3) #AND# (j #GE# w-7)) #OR#
                ((j #LE# w-11) #AND# (k #GE# w-16)) #OR#
                (k #LE# w-20) : nbs(i,j,k)));
!Constraint on the number of ships available each week;
@FOR( WW : s >= 2);
! Constraint due to the fact that further break must follow previous one;
! by at least 6 weeks;
@FOR( XX(i,j,k) | (j #LE# i-3) : nbs(i,j,k) = 0 );
@FOR( XX(i,j,k) | (k #LE# j-4) : nbs(i,j,k) = 0 );
!Constraint on total number of ships available;
@SUM( XX : nbs) <= 5;
! Imposing at least 2 ships available for 10 consecutives weeks from the sixteenth;
! to the twenty-fifth week (MARS IV);
@SUM( XX(i,j,k) | ((j #LE# 5) #AND# (k #GE# 9)) : nbs(i,j) ) >= 2;
```

```
! Fixing the demand;
@FOR( WW(w) | (w #LE# 14) : d(w) = 3);
@FOR( WW(w) | ((w #GE# 15) #AND# (w #LE# 25)) : d(w) = 4);
@FOR( WW(w) | (w #GE# 26) : d(w) = 3);
! Constraint of integer values;
@FOR( XX : @GIN( nbs));
END
```

ANNEX D
ORD PROJECT REPORT PR2003/03
MARCH, 2003

LINGO PROGRAM FOR THE CREW SCHEDULING PROBLEM

The following code is for the crew schedule when each crew is required to do 10 weeks of alongside tasks. These tasks are divided in five periods of 2 weeks. Different distributions of alongside tasks were also analyzed: (2*3 weeks + 2*2 weeks), (2*3 weeks + 1*4 weeks), (1*5 weeks + 1*3 weeks + 1* 2weeks), (2*5 weeks). The actual codes for these excursions is not provided but can be obtained from the authors, if required.
An additional internal function is used for the crew optimization code: IMPORT. This function allows a set of data to be imported. These data are used to define the crew demand (*s(w)*)

CODE FOR THE CREWS DURING THE SUMMER PERIOD

```
MODEL: ! Scheduling problem for MCDV, crews' schedule;
! We split the year in 2, 22 weeks for summer, 28 for winter. This
is summer;
!There are 3 breaks for summer: Leave time + 2 alongside break of
2 weeks each;
SETS:
  WW / 1..22 / : S, c; ! 22 operating weeks: Demand, crews
available;
  II / 1..12 / ; ! 12 possible first 2 weeks break;
  JJ / 1..12 / ; ! 12 possible second 2 weeks break;
  KK / 1..8 / ; ! 8 possible 3 weeks leave time;
  XX( II, JJ, KK) : nbc; ! nb of crews with break starting on week
i,j,k;
ENDSETS
! Objective function: demand for crews - crews available;
 MIN = @SUM( WW : @ABS(S-c));
! Computation of the total number of crews available each week;
! The breaks appears on intervals: [1,12], [9,20], and [10, 17]
@FOR( WW(w): c(w) = @SUM( XX(i,j,k) | (i #GE# w+1) #OR#
              ((i #LE# w-2) #AND# ((j #GE# w-7) #AND# (k
#GE# w-8))) #OR#
              ((j #LE# w-10) #AND# (k #GE# w-8)) #OR#
              ((k #LE# w-12) #AND# (j #GE# w-7)) #OR#
              ((j #LE# w-10) #AND# (k #LE# w-12)) : nbc(i,j,k))
!Constraint on the number of crews available each week;
@FOR( WW : c >= 2);
! Constraint due to the fact that 2nd break must be after 1st break;
```

```
@FOR( XX(i,j,k) | (j #LE# i-7) : nbc(i,j,k) = 0 );
!Constraints of no-overlap between the leave and the alongside
time;
@FOR( XX(i,j,k) | (k #LE# i-8) : nbc(i,j,k) = 0 );
@FOR( XX(i,j,k) | ((k #LE# j) #AND# (k #GE# j-3) : nbc(i,j,k) =
0 );
!Constraint on total number of crews available;
@SUM( XX : nbc) <= 5;
!Constraints for MARS IV training set from week 6 to 15;
@SUM( XX(i,j,k) | ((i #LE# 3) #AND# (j #GE# 8) #AND#
                  (k #GE# 7)) : nbc(i,j,k)) >= 2;
! Constraint of integer values;
@FOR( XX : @GIN( nbc));
! Fixing the demand. It is based on the optimal ship schedule;
DATA:
  S = @IMPORT( SSCHED.XLS, S);
ENDDATA
END
```

CODE FOR THE CREWS SCHEDULE DURING THE WINTER PERIOD

```
MODEL: ! Scheduling problem for MCDV, crews' schedule;
! We split the year in 2, 22 weeks for summer, 28 for winter. This
is winter;
!There are 3 breaks for winter: 3 alongside break of 2 weeks each;
SETS:
  WW / 1..28 / : S, c; ! 28 operating weeks: Demand, crews
available;
  II / 1..9 / ; ! 9 possible first 2 weeks-break;
  JJ / 1..9 / ; ! 9 possible second 2 weeks-break;
  KK / 1..9 / ; ! 9 possible third 2 weeks-break;
  XX( II, JJ, KK) : nbc; ! nb of crews with break starting on week
i,j,k;
ENDSETS
! Objective function: demand for crews - crews available;
 MIN = @SUM( WW : @ABS(S-c));
! Computation of the total number of crews available each week;
! The breaks appears on intervals: [1,9], [9,17], and [18, 26]
@FOR( WW(w): c(w) = @SUM( XX(i,j,k) | (i #GE# w+1) #OR#
              ((i #LE# w-2) #AND# (j #GE# w-7)) #OR#
              ((j #LE# w-10) #AND# (k #GE# w-16)) #OR#
              (k #LE# w-19)) : nbc(i,j,k))
!Constraint on the number of crews available each week;
```

```
@FOR( WW : c >= 2);
! Constraint due to the fact that 2nd break must be after 1st break
and 3rd after 2nd;
@FOR( XX(i,j,k) | (j #LE# i-7) : nbc(i,j,k) = 0 );
@FOR( XX(i,j,k) | (k #LE# j-8) : nbc(i,j,k) = 0 );
!Constraint on total number of crews available;
@SUM( XX : nbc) <= 5;
!Constraint for MARS IV training set from the 16th to the 25th
week;
@SUM( XX(i,j,k) | ((j #LE# 6) #AND# (k #GE# 9) : nbc(i,j,k) )
>= 2;
! Constraint of integer values;
@FOR( XX : @GIN( nbc));
! Fixing the demand. It is based on the optimal ship schedule;
DATA:
  S = @IMPORT( SSCHED.XLS, S);
ENDDATA
END
```

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The tasks assigned to the Kingston class Maritime Coastal Defence Vessels (MCDV) have strained the existing crew and ship resources A study by Benoit and Massel (2001) demonstrated that the level of demand on the ships used on average 95% of the available time-in-schedule for the fleet, leaving little scheduling flexibility The present study examined the policy of using multiple crews on the MCDV to determine if any scheduling improvements were possible. The results showed that multi-crewing is unlikely to yield gains in availability-for-at-sea tasking The possible consequences of implementation of the policy on the infrastructure, training requirements and crew cohesion were also discussed The methodology and analysis approach can be applied to other classes of ship

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